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Probabilities of Cold Injury to Black Currant

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Summary

Statistics have been produced which evaluate the probabilities of freezing or chilling injury to black currant during the sensitive preflowering and flowering development stages. Long period meteorological and cropping records from the National Fruit Trials, Brodgale Experimental Horticulture Station, Kent are used to give a comparison between long established and more recently introduced, late flowering, frost hardy cultivars. Yield losses are related to instances of low temperatures to place some extreme events into a historical perspective.

Introduction

For many years a comparatively early flowering black currant cultivar, Baldwin, has been the mainstay of the British black currant industry. This cultivar has many desirable attributes but its early season of flowering has resulted in an uneven cropping record with the worst seasons producing little or no marketable yield. More recently, new cultivars which have emerged from an intensive breeding programme at the Scottish Crop Research Institute, Dundee, have presented growers with an opportunity to greatly improve their chances of more regular cropping. Prominent among the new cultivars is Ben Lomond which combines later flowering and frost hardiness with good processing qualities (Anderson, 1976). However, due to their short cropping history, a comprehensive appraisal of their cropping characteristics is not available. This problem can, in part, be circumvented by accepting the flowering records to date as representative of the longer term.* Long period meteorological records can then

* The flowering record of Baldwin indicates that the average date for grape stage during the 1979-84 period is 4 days later than the 1960-84 mean. By the end of flowering the difference is 1 day.

be analysed to create a versatile and accurate climatology. Frost risk or cold risk, below a variety of bases, and covering a range of dates can be compared directly for particular cultivars and the benefit of later flowering and/or cold tolerance quantified.

Previous studies into the climatology of spring-time frosts have been of a more general nature but have set precedents for the form of analysis now presented ie Hogg, 1950; Lawrence, 1952; Roe, 1981; Barrie 1983.

Probability of individual cold events

An analysis was carried out to determine the likelihood of low temperatures during April and May using the meteorological records from Brogdale for the years 1960 to 1984. The probabilities of single cold events are expressed as 'n' years in ten. Figure 1 illustrates the probability of at least one air minimum temperature occurring after the 1st April, 8th April etc and up to the 2nd June. Any temperature between +3°C and -3°C can be selected which allows for chilling as well as freezing injury to be studied. Taking the median dates for date of first open flowers of two cultivars, Baldwin (17 April) and SCRI P 9/8/7 (9 May), then the probability of recording at least one air frost after these dates is 7 years in 10 and 1.4 years in 10 respectively. If a degree of frost tolerance is included for SCRI P 9/8/7, allowing a lower temperature limit of -1°C to be chosen, then the probability falls to below 1 year in 10.

Probability of sequences of cold events

Sequences of cold days during the reproductive phases of a plant will have a more deleterious affect than will isolated instance of cold injury, given events of similar severity. Sequences of consecutive days with minima below a variety of base temperatures are given for Brogdale in figure 2. Thus, a consecutive period of 3 days during May recording air minima $\leq$ +2°C is likely for 1.3 years in 10, on average. There is a bias in this data, for the probability of a particular event will decrease as the month progresses. This bias is shown in fig 3 where it can be seen that there is a probability of 2.7 years in 10 for a run of 2 consecutive minima $\leq$ 2°C after the 1st May, while the same event after the 20th May will only occur on average, 0.6 years in 10.

Comparison of cultivars

The average dates, per cultivar, for grape stage to end of flowering can be expressed in a form compatible with fig 1. The median date for grape stage for Ben Lomond (table 1) is the 13th April, and the end of flowering the 12th May (Anderson et al, to be published). The chance of an air frost after the 12th May is very small (from fig 1, p = 8%) so the probability curve for Ben Lomond at grape stage will be very similar to line C in fig 1; cv Ben More close to line D, etc. In this way any cultivar can have an associated probability of cold injury during a particular growth stage.

Data extracted from figure 1 highlights the advantages which the later flowering cultivars have in avoidance of frost, especially after first open flowers stage, see table 2.

Table 2. Years in ten probability of an air frost after 3 flowering stages (median dates). Brogdale, 1960-84.

Stages of floral development	Baldwin	Ben Lomond	Ben More	SCRI P 9/8/7
Grape stage	8.7	7.5	5.5	3.7
First open flower	7.0	5.9	4.0	1.4
Full flower	3.7	1.8	0.6	0.4

Thus Baldwin may expect at least one air frost in most years even after the date of first open flowers while SCRI P 9/8/7 will avoid an air frost in most years between the dates of grape stage and end of flowering. An air frost affecting SCRI P 9/8/7 after first open flowers stage will be a comparatively rare event.

Discussion

The physiological responses of black currant blossom to frost or chilling injury is beginning to emerge. There is growing evidence that cold tolerance depends on 1) the severity of the temperature 2) the stage of flower development 3) the cultivar 4) the weather during the late summer and autumn and 5) possibly temperatures in the months preceeding grape stage.

Results from cold chamber experiments indicate that, common among all cultivars, a severe frost will produce a lower survival of flower buds than will a slight to moderate frost. (Dale 1981). However, the percentage survival of viable blossom which subsequently sets and produces mature fruit is also influenced by the timing of the cold treatment. Over a broad spectrum of treatments the survival rate decreased as the black currant flowers developed from grape stage to full flower (Dale 1981, 1984). There is also a marked distinction between cultivars, with cold and frost tolerance more evident in cultivars bred from selections of Scandanavian or Finnish origin. Regardless of the timing or severity of the cold treatment the ranking between cultivars is unaltered (Dale and Heiberg, 1984).

The frost tolerance of a black currant cultivar may also fluctuate from year to year as the level of carbohydrate in the floral tissue reacts to temperature levels during February to April. A relationship between carbohydrate content in apple blossom and spring temperatures has been determined by Miller and Jackson (to be published). Frost hardiness in apple blossom was seen to decrease following a simulated warmer than average spring with accompanying low carbohydrate levels. Conversely, a cold early spring period will lead to high carbohydrate levels and relatively good frost hardiness.

It must be noted that air temperature is only an approximation to the tissue temperature of a bud or flower of any plant. Under some, quite common, circumstances it has been shown that apple bud and blossom temperatures will be around 2°C colder than the surrounding air (Landsberg et al, 1975; Hamer, 1980). The differences will probably be similar for black currants and may be expected in the UK during a cloudless night with light winds. On a particularly clear night the loss of outward long wave radiation from the surface may reach 100 Wm^{-2}, under partly cloudy conditions the loss will be around 40 Wm^{-2}; see fig 4.

Detailed records of long wave radiation are not available from Brogdale so they cannot be included in this climatology. However, the effects are important and should be at least borne in mind when studying the data.

Extreme yields related to air temperatures

During several years between 1960 and 1984 crop yields fell below 3.8 t/ha at Brogdale (mean yield = 7.73 t/ha; st. dev. 5.72 t/ha). For most of these years

an unusual cold event with a probability of less than 1 year in 10 can be found to provide a likely explanation, see table 3. Other factors which could contribute to low yields, ie plant diseases and disorders have not been taken into account.

Table 3. Low yield years and temperature events: Brogdale EHS

Year	Yield (t/ha)	Flowering stage	Temperature event (°C)
1960	3.04	FF	Tn = 0.0 27/4. 28/4
1961	2.91	GS to FOF	Early season, frosts in March
1968	3.51	GS to FOF	Tn < 1° 3/4 - 15/4 (13 nights)
1969	0.93	GS to FOF	Tn = -4.4, 20/4
1971	2.28	FF	Tn = -1.6, 30/4
1977	1.23	FF	Tn = -2.5, 19/4

GS = grape stage : FOF = first open flower : FF = full flower
Tn = minimum air temperature.

In this table only the most unusual temperature event each year has been noted. During several of these years there were other more probably cold events which may have compounded cold injury.

Coversely during the years which recorded the highest yields 1965 (15.97 t/ha), 1975 (18.23 t/ha), 1979 (17.37 t/ha) and 1983 (24.10 t/ha) the period between dates of grape stage and end of flowering was virtually free of air frosts.

Simple regression techniques relating minimum (or mean) air temperatures during floral development to the subsequent yield have been proposed by Anderson et al (to be published) and Smith (1967). These regressions meet with some success but in general the response of a plant during reproduction to the interactions of different weather conditions make an objective approach to the problem very difficult (Williams et al, 1984).

Conclusions

Successful black currant growing is heavily dependant on weather conditions, particularly temperatures during flowering in April and May. In breeding new

cultivars to be 1) cold tolerant and 2) late flowering, long term temperature statistics can be used to evaluate the probabilities of avoiding cold injury and thereby achieving more regulated cropping.

Ben Lomond represented a major improvement in terms of cold tolerance and Ben More in terms of later flowering. More recent hybrids, SCRI P 9/8/7 and SCRI P 8/12/7, combine both of these qualities. The scope for further improvement in this field is now more limited. Progress in the SCRI breeding program has produced varieties like SCRI P 9/8/7 which, relative to Baldwin, have reduced the probability of an air frost after grape stage by around 60%, after first open flowers by 80% and after full flower by nearly 90%. Despite these great improvements the latest flowering hybrids may expect at least one occurence of sub-zero air temperature after grape stage for 4 years in 10, on average. Any cultivar which flowers one week later than SCRI P 9/8/7 would half this probability.

Further improvements in frost and cold hardiness are being sought at the SCRI by breeding cultivars which are more frost and cold hardy at grape stage and which also retain more of their hardiness after first open flowers stage.

Key words. Black currant, cold injury, climatology.

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Table 1. Median Dates of Four Flowering stages and Six Cultivars at Brogdale

	Grape stage	First open flowers	Full flower	End of flowering
Baldwin (1960-84)				
1st quartile	29 March	9 April	24 April	4 May
median	5 April	17 April	1 May	9 May
3rd quartile	13 April	22 April	5 May	13 May
Ben Lomond (1974-84)				
1st quartile	6 April	17 April	30 May	7 May
median	13 April	22 April	6 May	12 May
3rd quartile	17 April	29 April	10 May	15 May
Amos Black (1960-68; 1973-75)				
1st quartile	11 April	20 April	3 May	12 May
median	14 April	22 April	7 May	15 May
3rd quartile	20 April	28 April	13 May	19 May
Ben More (1978-84)				
1st quartile	22 April	29 April	14 May	19 May
median	24 April	30 April	15 May	21 May
3rd quartile	29 April	5 May	18 May	24 May
SCRI P 8/12/7 (1979-84)				
1st quartile	27 April	1 May	16 May	22 May
median	29 April	7 May	19 May	25 May
3rd quartile	30 April	9 May	20 May	27 May
P9/8/7 (1979-84)				
1st quartile	25 April	6 May	17 May	22 May
median	1 May	9 May	19 May	24 May
3rd quartile	1 May	13 May	27 May	2 June

Source: Anderson, Barrie and Williams (to be published)

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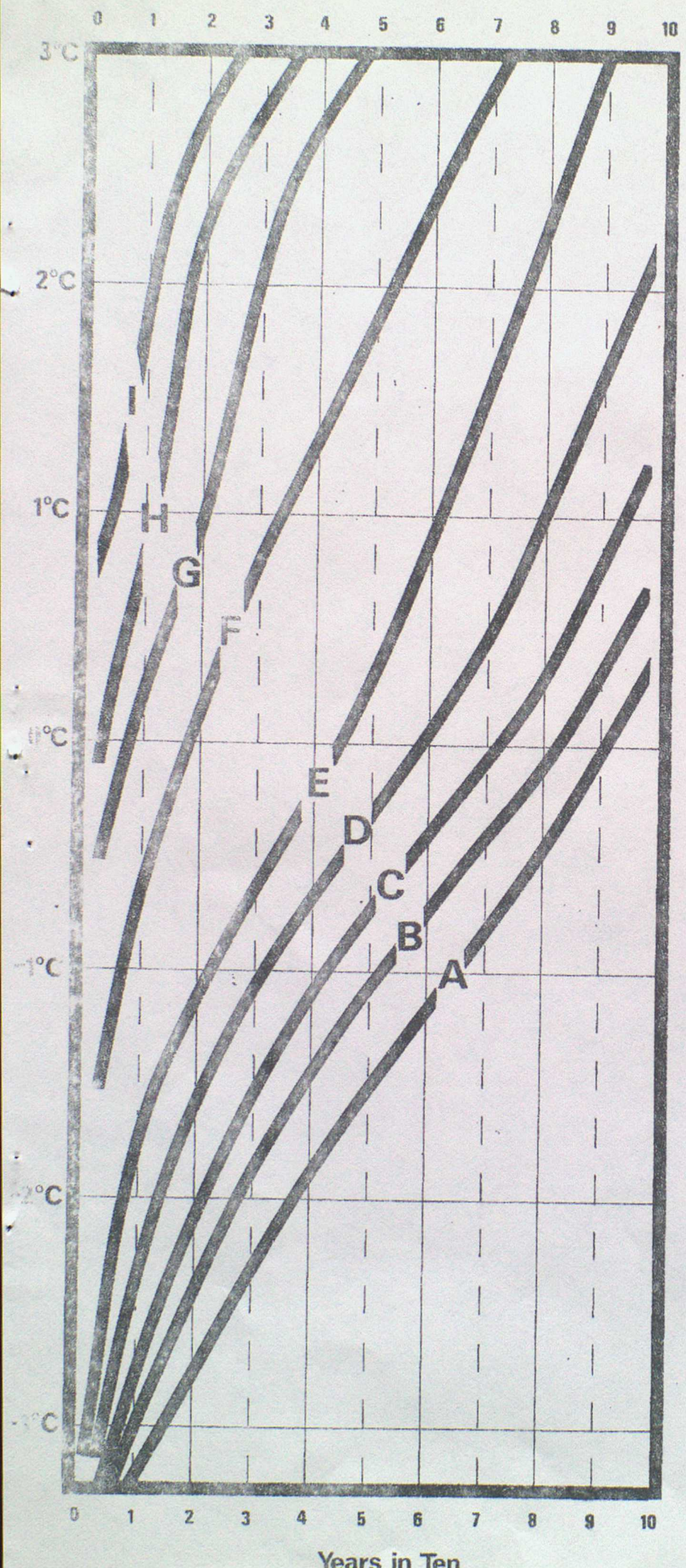
Brogdale 1960~84

Probability of at least one air temperature ≤ given limits during the Spring



A · 1 Apr. – 2 June
B · 8 Apr. – ..
C · 15 Apr. – ..
D · 22 Apr. – ..
E · 29 Apr. – ..
F · 6 May – ..
G · 13 May – ..
H · 20 May – ..
I · 27 May – ..

Fig.2

Brogdale 1960~84

Probability curves for air minimum temperature ≤ stated thresholds on consequtive nights during May

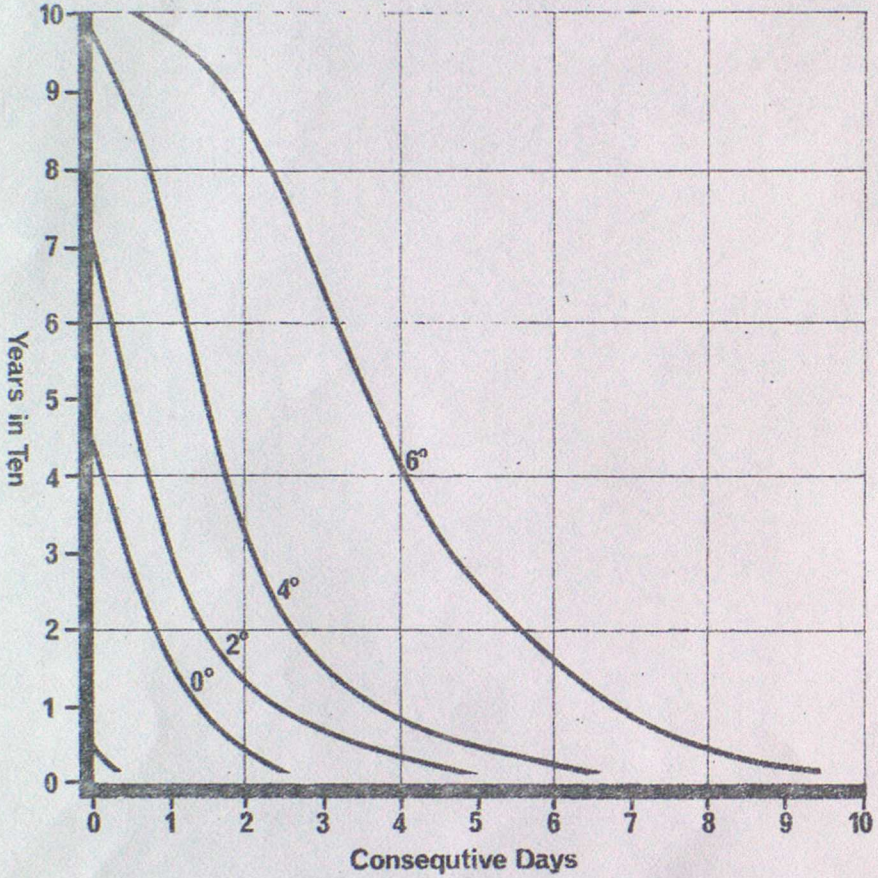
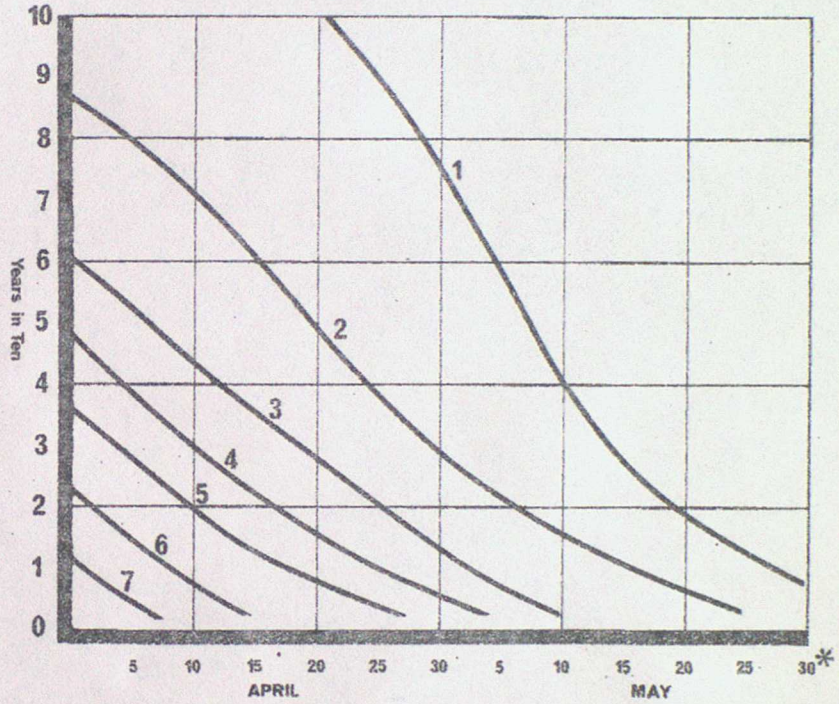


Fig.3

Brogdale 1960~84

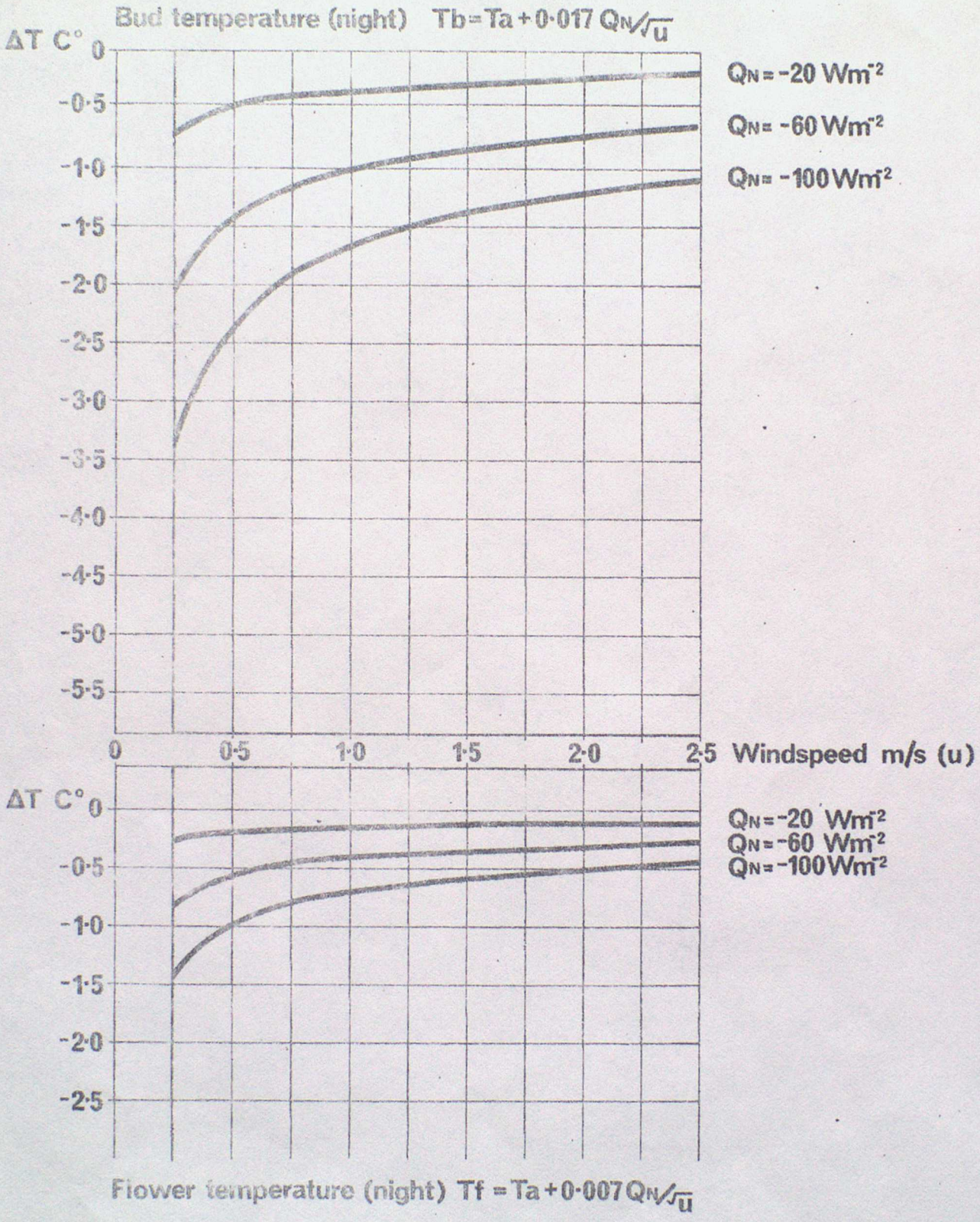
Probability of consequtive days with air minima ≤2°C



* sequences starting on, or before, 30th May continued until broken

Fig. 4

Departure from air temperature of apple bud and flower temperature



Landsberg, Butler & Thorpe 1974